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CANMET
Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

BIOTECHNOLOGY POSITION PAPER

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BIOTECHNOLOGY
Position Paper

Energy, Mines and Resources Canada
Hon. Jake Epp, Minister

Énergie, Mines et Ressources Canada
L'hon. Jake Epp, Ministre

Canada

THE ENERGY OF OUR RESOURCES

THE POWER OF OUR IDEAS

Biotechnology

Position Paper

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Prepared by R.G.L. McCready and M.C. Campbell
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Introduction

This Biotechnology Position Paper outlines the current status of the CANMET Biotechnology Program and develops a strategy for this program to comply with the current cost recovery policy of the government and addresses the maintenance of the BIOMINET Network following the eventual loss of Strategic Technologies Funding from Industry, Science and Technology Canada.

Clients for Biotechnology Applied to Resources

Industry, Science and Technology Canada and other Government Agencies

CANMET receives a significant amount of funding from ISTC and must justify the use of these funds to that department, we must consider ISTC as our major client. CANMET has a representative on the Interdepartmental Biotechnology Committee and on the Biotechnology Executive Committee. Representatives from ISTC have stated that "BIOMINET is the most active and effective of all the National Biotechnology Networks". In fact, in the last year CANMET was provided an additional $350,000 from the ISTC Biotechnology Strategy Funds to initiate a biotechnology program in the fossil fuel sector. This brings the funding to $705,000 for fiscal years 1990/91 and 1991/92. Further, CANMET is often asked to assess biotechnology proposals submitted to the ISTC Strategic Alliance Program, the NRC IRAP Program and to other research programs within other Federal departments. CANMET also has a representative on the Interdepartmental Acid Mine Drainage Technical Committee to provide advice to Transport Canada on the acid drainage problems at the Halifax International Airport.

The Mineral Industry

As the Biotechnology Section is an integral part of the Mineral Sciences Laboratory, our major industrial clients are the many mining companies which are active within Canada. However, as this industry has depended on chemical and physical processes throughout it's lifetime, many of it's members are very reluctant to consider biotechnological processes as a possible integral part of their operation. Many of it's members must be very confident in the utility of bioprocesses before they will support them in their industry. They are reluctant to themselves pay to be convinced. Herein lies the paradox which plagues BIOMINET and the Biotechnology Section of CANMET.

The Fossil Fuel Sector

After a rather successful development of the National Biotechnology Network (BIOMINET) and the development of several biotechnological processes for the mineral industry, CANMET decided to enlarge the BIOMINET activities into the fossil fuel sector. One of the Canadian oil companies has a strong biotechnology group within their existing research centre, however, most of the major oil companies are monitoring biotechnological activities or are supporting external biotechnological research, with a"wait and see" attitude. Since the oil industry has had to contend with biological problems such as biofouling of process streams and bacterial internal and external corrosion of pipelines they appear to be more receptive to biological processes than their counterparts in the mineral industry.

The Market

The Mineral Industry:

The Canadian mineral industry, with few exceptions, is very conservative and reluctant to adopt non-chemical or physical processes in their mineral recovery systems or milling circuits.

Their support of innovative ideas fluctuates with the price of metals. Support for research has increased to address environmental problems; support for development of a biological process is only considered after all possible chemical or physical alternatives have been exhausted or proven uneconomic.

A significant potential for growth in the application of biotechnology in the mineral industry is foreseen in the environmental area. The development of biological processes, including engineered wetlands, have advanced to a point where the industry is actively supporting the research and development in this area. As the current low metal prices are expected to continue through the 1990's, the industry will be restrained in supporting the development of new biological processes for the recovery of metals from dilute drainage, to degrade flotation organics present in recycled tailings water, to examine microbial polymers as additives for flotation and agglomeration or to assess the feasibility of bacterially leaching a specific mineral deposit.

To date the major support of the cost recovery work conducted by the Biotechnology Section has been from Transport Canada and Alcan. Other companies have provided minimal support with small, $5,000-10,000 contracts for consulting or quick-and-dirty feasibility studies for specific problems.

The Fossil Fuel Industry:

The oil and gas companies seem more open to investigating and applying biotechnological processes to resolve some of their industrial problems. They are actively seeking ways to optimize the recovery of oil from proven reservoirs and are conducting research or keeping abreast of research developments in microbial enhanced oil recovery (MEOR), biocorrosion of pipelines and microbial degradation of petroleum and petroleum by-products. Several companies have indicated that they would like to form a research consortium where each company would buy into generic biotechnology research conducted by CANMET. This approach has not been successful to date with any members of the mining industry, but has proven successful in the case of the hydrogen research group supported by the fossil fuel industry.

Although oil prices have been depressed for some time, albeit with some price spikes, the lack of an alternative fuel in the near future dictates that the demand for petroleum products will continue; growth is most likely as the population continues to increase. Prices, therefore, are expected to strengthen over the longer term.

The Biotechnology Product

Bacterial Leaching:

CANMET research has indicated that the application of underground bacterial leaching as a means of recovering metal values is a site specific process which is dependent on the amenability of the ore to leaching, the spatial configuration of the ore body, the breakability of the ore, and the commitment of the senior mine officials to make the process succeed. Some ores are not good candidates for leaching due to their poor breaking characteristics, high acid consuming potential or presence of toxic minor elements.

CANMET has not pursued the bacterial preoxidation of refractory gold ores or concentrates as there are several commercial companies within Canada that are actively pursuing process development.

CANMET would only initiate further research on bacterial leaching for a site specific assessment of a particular ore body with total financial support from the mining company.

CANMET has investigated various biological control schemes to prevent the development of acid mine drainage in tailings. Bacterial predators, the application of biocides and other microbial inhibitors have proven to be unfeasible due to extreme toxicity or lack of effectiveness under acidic conditions.

The best chance of success in preventing or treating acid mine drainage from tailings dumps at the present time appears to be an ecologically engineered system to develop a biological cover which will eventually provide

an organic sealing layer over the tailings thereby preventing percolation of air and water into the reactive sulphide tailings. Concurrently, CANMET has developed a biolcgical system for the treatment of small acidic seeps. This system is currently being field tested at the Halifax International Airport and to date the results have been very promising. A very recent, promising development has been the concept of forming, *in situ*, an oxygen depleting, water retaining bacterial exopolymer layer over the surface of the tailings combined with a vertical biobarrier along the inner face of the dams. These biobarriers will prevent the ingress of water and oxygen into the tailings thereby preventing the oxidation of indigenous sulphide minerals.

Metal Sorption:

CANMET is currently running a pilot-plant study on the biosorption of uranium from Denison bacterial leach liquors.

To date a fortyfold concentration of uranium has been observed but there have been some problems with competing ions gradually reducing the loading capacity of the biomass. The process has been re-designed and will be assessed over the coming year. Once this task is completed the process should be ready for commercial use either to remove residual uranium from the yttrium plant feed at Denison or for the underground concentration of leach solutions to reduce the amount of liquid which must be pumped to surface.

CANMET has recently initiated a project to assess various microorganisms for the uptake of specific metal ions. Specific adsorbants are being sought for nickel and cadmium. This project is also supported by contract work to survey a wide range of microorganisms for their metal uptake capacities. Should biosorption of metals prove to be feasible and economically attractive this technology could be utilized to remove metal ions from industrial waste streams, recover metal values from leach pregnant liquors, or to remove toxic metals from potable waters.

Mitigation of AMD

Over the past few years CANMET has contracted out about $350,000 for the development of ecological engineered wetlands and biological studies on the treatment of acid seepages. In the past two years CANMET has developed a microbial ecosystem approach suitable for small acidic seepages and it is currently being field tested at the Halifax International Airport.

Degradation of Organics

CANMET has undertaken several small projects on the degradation of organics associated with mineral recovery and in the fossil fuel sector. CANMET has patented two biological processes which are currently being pilot-planted or negotiations are underway to pilot-plant. We have also completed a project on the biodegradation of flotation reagents and agglomerating agents in the tailings re-cycle water at a specific mine site. CANMET is also supporting the development of a biological process for the degradation of refinery sludges and doing some work for AMOCO Resources on the biological degradation of tri and tetraethylene glycol in one of their waste streams. There is a lot of potential for the development of biological processes to specifically degrade organics in mineral or fossil fuel process and waste streams.

Enhanced Oil Recovery

Although BIOMINET and the Biotechnology contract funds are not currently supporting work on microbial enhanced oil recovery (MEOR) we have kept abreast of developments in this area which are supported by ERL under the 50:50 Energy Program.

Biofouling and Biocorrosion

MSL Biotechnology in cooperation with MTL, the University of Waterloo and Nova Husky Research Corporation (NHRC) have initiated a joint project to determine whether or not crack growth initiated by stress corrosion cracking is accelerated due to bacterial activity. Further under the Biotechnology program in the fossil fuel sector, NHRC are assessing various commercial biocides to prevent the biofouling of secondary water injection systems for the recovery of conventional and heavy oils. In this study, the development of anaerobic tubercles are also being assessed and the biological initiation of corrosion is being studied. CANMET has also supported research on the application of the hydrogenase field assay kit for detecting the presence of sulphate reducing bacteria (SRB's) in oil storage facilities and in pipelines. This test

was specifically developed to determine the presence of SRB's in soils adjacent to pipelines where corrosion was occurring.

Biodegradation of Refinery Sludges

CANMET has supported the development of a biological process to degrade slop oil and refinery sludges which has been undertaken by NHRC on a 50:50 contract basis. The contractor is currently trying to form a strategic alliance with an engineering group to design a pilot-scale reactor which will be tested at the Husky Oil Lloydminister refinery. If successful, a full scale reactor will be constructed to facilitate the degradation of wastes from the new heavy oil refinery currently being built in Lloydminister.

Microbial Plugging of Formation Porous Zones

CANMET is currently partially supporting the development of a biological/chemical process for plugging off sand or gravel lenses, or unconsolidated zones encountered during drilling of new oil wells. At present some wells required triple casing to drill through porous zones. If this technology proves effective, a savings of $150,000 per well could be realized due to the reduction in the amount of casing required.

Information Source and Networking

Over the past five years CANMET has acted as the secretariat for the BIOMINET Biotechnology Network. Quarterly newsletters, annual meeting proceedings, and an educational workshop have been published. The workshop has been presented in three different geographical regions over the past four years and CANMET also co-chaired and co-sponsored the International Symposium on Biohydrometallurgy in Jackson Hole, Wyoming in August, 1989.

The secretary of BIOMINET receives an average of three phone calls per week seeking advice on specific mining problems or requesting the names of individuals or research groups having expertise in particular areas.

The Deliverability

Capability

The CANMET Biotechnology Group has expertise in all areas of bacteriology but is relatively weak in mycology and bio-engineering. Generally, new processes are developed on the bench, scaled up to a laboratory pilot-plant study, then taken to a field pilot-plant study prior to advancing to commercial scale. Due to the relatively small size of the Biotechnology Group, projects are selected and pursued only when the group feels fairly confident of succeeding in the development of a process to resolve the particular problem. As a team approach is taken to every project, we tend to limit the number of ongoing projects at any one time.

Timing

To date, the Biotechnology group has not actively solicited cost recovery projects but has been approached by the industry and has accepted only those projects which it felt it could successfully complete and resolve the particular problem. The number of cost recovery projects is limited by the availability of personnel, the availability of analytical facilities, especially for the analysis of organics associated with the fossil fuel sector such as crude oil, coal tars and refinery sludges.

Price

Industry is reluctant to contract CANMET to conduct projects on the development of new biotechnological processes which they feel are unproven to date. It is very difficult to convince industry that a biological process is economic and that there will be a good return on investment until the pilot-plant data have been obtained. At present the industry will not support ideas for biological processes with cash, and will only offer limited support once the laboratory pilot-plant data are available. Even then they are reluctant to proceed in the development of a biological process. Many potential cost recovery clients feel that the charge out rates for CANMET personnel are high and the intellectual property conditions may be problematic to some.

The Strategy

The CANMET Biotechnology group has always developed sufficient data to prove to the industry that the biological process is feasible, prior to soliciting industrial support to pilot-plant or commercialize a process. With very few exceptions, CANMET cannot approach the industry with a project proposal and expect to receive financial support for the research. The whole industry, with a few exceptions, has an "I'm from Missouri" mentality and wants to be shown the results of the laboratory pilot-plant studies prior to even considering financial support of the project and a possible industrial scale pilot-plant. To date, CANMET has, with few exceptions, had to push the industry into considering biological processes for resolving their problems. Where the industry has accepted the challenge, they have been very satisfied with the results and reported economic gains from the application of biotechnology.

In the future CANMET must convince companies of the potential benefits of various biotechnological processes and attempt to obtain industrial support for projects as early as possible.

The Mechanisms

BIOMINET

Over the past six years CANMET has very successfully used the BIOMINET Network to develop consortia to attack specific biotechnological problems or to develop new processes. Using the Biotechnology National Strategy Fund, CANMET has contracted out specific projects or encouraged various consultants, Provincial Research Organizations (PRO's), universities or specific companies to work co-operatively in developing new processes or resolving problems for the industry.

Currently the networking activities of BIOMINET are supported with funds from ISTC. These funds will not continue ad infinitum, and when this funding ceases CANMET may have to implement a membership fee for BIOMINET. Such a fee may be set at $100.00 per company and $15-25 per individual; we do not want to have a high individual fee as we would lose many of our academic colleagues, interested, non-affiliated members and small one-man consulting firms as members. Secondly, CANMET may have to charge a registration fee for the annual BIOMINET meetings, workshops and courses; a fee of $50.00 per individual has been suggested.

Members have suggested piggy-backing BIOMINET with various scientific societies and their meetings, however, not all members of BIOMINET are members of the CIM or the Canadian Society for Microbiologists. As biotechnology is a multi-disciplinary endeavour, it is impossible to select one canadian scientific society which would reach all of the current BIOMINET members.

CANMET

The Biotechnology Section coordinates it's Fossil Fuel Biotechnology Program with the Energy Research Laboratory so that there is no duplication of effort between biotechnology and the 50:50 Energy Program. The mineral biotechnology program is co-ordinated with MEND to assure there is no duplication. The section is currently working cooperatively with the Metals Technology Section on the biocorrosion of pipelines and on crack growth following stress corrosion cracking of pipeline steel.

In the future, when ISTC funding ceases, the CANMET external contract funds for biotechnology will be severely reduced as they will have to come out of the MSL A base funding. At such a time, all contracts will have to be 50:50 cost shared and the number of new initiatives per year will be minimal. Such a change in funding will severely effect the submission of research proposals by academics, small private research companies and some of the PRO's as they would have to seek 50% of the project cost from an industrial partner.

Consortia

As mentioned previously, CANMET has supported various consortia to conduct biotechnological research. When the National Strategy Funding ceases the Biotechnology Section may have to form consortia with PRO's, consultants and private research companies in order to lever research funding from industry. CANMET may approach MITEC to facilitate the development of industrial consortia to support generic or

specific project research by the Biotechnology Section.

CANMET may form research partnerships with companies, PRO's or university groups where the expertise of the two groups are complimentary. For example a research partnership with Ortech International could be applicable to mineral processing or environmental problems. CANMET would provide the microbiological expertise and Ortech would provide the mineral process engineering and engineering design for such joint projects.

Recommendations:

Biotechnology is a Strategic Technology which is applied predominantly in the areas of environmental protection and increasing productivity. A policy issue which is presently upon us is the current development of Regulations for Biotechnology Products under the Canadian Environmental Protection Act.

The CANMET Biotechnology Program has been very successful over the past six and a half years. Commercial bacterial leaching of uranium has been achieved. We have solved a biofouling problem for Quebec Cartier Mines. Transport Canada is currently planning a pilot-plant study on the biodegradation of de-icing fluids. We assisted AMOCO Oil optimize the biodegradation of tri-ethylene and tetra-ethylene glycol in their refinery waste stream. We are pilot-planting AMD mitigation at Halifax Airport and plans are being developed to bring the system to full-scale. We have proven that coal tar can be biodegraded economically. We are currently pilot-planting the recovery of uranium from dilute, complex process solutions by biosorption.

The withdrawal of ISTC Biotechnology Funding in the near term would create great difficulty in sustaining the development of biotechnology applications for the benefit of the mineral and fossil fuel sectors. Industrial support of the biotechnology program will increase slowly over an extended period of time as the currently developed biotechnological processes move from pilot-plant studies to commercial entities. As Resource Sector Biotechnology is in its infancy, the major support for the program must be provided by public funds, although industry acceptance of biotechnology is gradually increasing. Support for the Biotechnology Program will only be forthcoming from the industry when several biotechnological processes have been proven through industrial use. Major CANMET support will be required to develop biological processes for the protection of the environment and to optimize mineral and fossil fuel production for at least the next five years.

Industry will only provide financial support for a specific project once there is sufficient data and evidence for them to to conduct a cost/benefit analysis. CANMET has been advised by industry to foster the early work in biotechnology projects by providing 50:50 funding; by carrying out complementary projects in-house which industry alone cannot undertake due to lack of pilot plant facilities or specialized equipment; by providing additional R&D expertise to enrich industry projects or by contracting out the services of an EMR specialist for specific tasks in industrial research projects as required.

CANMET proposes to develop research consortia or partnerships with PRO's, private research companies or with industrial companies to conduct research and process development for specific industrial problems on a cost recovery basis. However, industry has stated that they would be much more receptive to conduct joint research projects with CANMET if each organization paid their own research costs.

Industry representatives have suggested that CANMET consider a new formula for industry funding which would increase the industrial contribution as confidence in the process increases. They have suggested starting with 0-10% industrial support for the proof of concept, then 33-50% for prepilot studies and finally 50-100% for pilot plant studies. Such a formula still allows a great deal of flexibility, but shows industry that a growth in commitment is expected.

CANMET may solicit help from MITEC to form industrial consortia to support CANMET research on generic research issues or on specific processing or environmental problems which affect a number of the industrial clients eg. biodegradation of cyanide.

CANMET may be able to form industrial consortia in the fossil fuel area to conduct research on souring of gas and oil during secondary recovery, internal and external biocorrosion of pipes, biodegradation of oil spills and the *in situ* degradation of gas and oil leaks from underground tanks.

Industry and the general BIOMINET membership may be required to provide financial support to CANMET to act as the secretariat of the BIOMINET Network if they wish for it to continue as a liaison between the researchers and the industry and as a source of information on biotechnological developments world-wide. CANMET will continue to act as the hub of the BIOMINET Network. BIOMINET meetings and workshops will be tailored to focus on specific industrial interests, eg. environmental problems and biocorrosion and will locate meetings in the client communities.